PHOTOCLINOMETRIC STUDIES OF CRATER AND GROOVE MORPHOLOGY ON PHOBOS: D. C. Munro and L. Wilson, Environmental Science Division, Institute of Environmental and Biological Sciences, Lancaster University, Lancaster, LA1 4YQ, United Kingdom.

Abstract

The surface of the larger of the two martian moons, Phobos, is peppered with impact craters and criss-crossed by a distinctive set of linear grooves [1]. Descriptions of the morphology of these features may be used to make inferences about the surface properties of Phobos and to constrain the mode of formation of the grooves. This abstract describes photoclinometric profiling of impact craters and grooves on Phobos using the Hapke photometric function [2, 3] to describe the surface reflectance. Lines of pixels from Viking Orbiter images were used to calculate topographic profiles for selected impact craters and grooves. These profiles allowed examination of the variation in width, depth and topography of individual features with the aim of formulating general descriptions of crater depth to diameter ratios, crater rim heights, groove width to depth relationships, groove rim characteristics and patterns of variation along grooves.

Methodology

Photoclinometry uses a description of the variation in surface reflectance with angles of observaton and illumination, i. e. a photometric function, to calculate the slope of individual image pixels and thereby construct topographic profiles [4, 5]. The choice of photometric function has previously been shown to be the major source of error in calculation of topographic profiles by photoclinometric methods [6]. Although simpler photometric functions such as the Minnaert or lunar-Lambert functions have been shown to be adequate for most photoclinometric applications [7], the subtle nature of topography associated with grooves on Phobos required that possible errors be minimized. For this reason the Hapke function [2, 3], with its detailed consideration of multiple scattering and the effects of unresolved macroscopic roughness provides the best possible description of the photometric properties of planetary regoliths [6] and was used in this research as a basis for the calculation of local surface tilts of pixels in Viking Orbiter images. The basis of the technique is to compare the reflectance of each pixel with that calculated for a flat surface under identical illumination and viewing geometry and thereby estimate local surface slope.

Scans of pixels were selected from the Viking Orbiter images to traverse impact craters and grooves such that; 1) the beginning and end of each scan could be estimated to be flat and at approximately the same elevation; 2) the scan was co-planar with the illumination vector; 3) the orientation of the scan was perpendicular to the strike of local topographic slope and; 4) variation in reflectance could be assumed to be due to local topographic slope and not to composition. Using the spherical harmonic expansion model of Duxbury [8] to describe the shape of Phobos and the accompanying ephemeris data from Viking Orbiter images to calculate the local viewing geometry, the incidence, emergence and phase angles for each pixel within a scan were calculated thereby removing the effects of the irregular shape of Phobos from the calculation of topography.

Two difficulties arise in the application of the Hapke photometric function to studies of topography from photoclinometry on bodies on which the detailed properties of the regolith are poorly constrained; 1) the determination of the reflectance of a flat surface; and 2) estimation of $\bar{\theta}$ which describes the rms variation in surface roughness of the surface at sub-pixel resolution and thereby influences the shadowing function. Commonly, Flat Surface Reflectance (FSR) is estimated to be the mean value of the entire scan. However, a consideration of the effects of errors in estimation of FSR [6] reveals a characteristic tilting of topography towards and away from the source of illumination in cases of under- and over-estimation of FSR, and thus the correct value for FSR can be experimentally determined by variation of FSR until profiles commence and end at the same elevation. Typically values of FSR used in this research fell

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within a narrow range of 101 - 104% of the mean value for the entire scan. Constancy of $\bar{\theta}$ is assumed on the basis of the absence of ejecta blankets [9] and of downslope movement of regolith within the craters. The second constraint is valid only for craters that are less than 1 km in diameter as the appearance of craters larger than this in Viking Orbiter images (e.g. Roche [10]) suggests that downslope movement of regolith within the crater may occur, implying variation in $\bar{\theta}$. The best results in this research were achieved using a narrow range of values from 36° to 38°.

Results and Discussion

The photoclinometrically produced profiles confirm earlier observations that impact craters on Phobos typically show a simple bowl shaped morphology [1]. Crater rims are typically only slightly raised with respect to the surrounding topography (2 - 3% of crater depth) but also may be markedly more prominent (5 - 7% of crater depth). This implies either variation in material properties or the effect of the variable tendency for downslope regolith movement of Phobos [11]. Depth to diameter ratios are between 0.05 and 0.143. Using the set of observations in this research (minimum depth 6.85 m - maximum depth 100 m) no marked changes in crater depth to diameter ratio were observed.

The grooves on Phobos show a complex range of morphologies that have been variously linked to the modification of fractures within the body [1], the impact of ejecta from cratering events on the body itself [12, 13], and the impact of ejecta on Phobos from the major basin forming impacts on the martian surface [14]. Measuring groove morphology via photoclinometry confirms the presence of raised rims around some grooves [14] and additionally indicates that there is a marked asymmetry of these rims that may persist along the length of a groove or may occur intermittently and vary markedly with position. The variation in rim development and rim asymmetry indicates that groove formation by the action of impact ejecta is a viable mechanism in many cases. Secondary modification of pre-existing fractures by the release of volatiles is also consistent with the observed morphology but the absence of marked albedo changes along the groove rims and the assumption of a constant $\bar{\theta}$ implicit in the approach precludes assessment of such models. Groove depth and width varies with position and shows no consistent pattern along the length of individual grooves. Where it is possible to examine grooves with a "beaded" appearance, adjacent pits may differ markedly without any consitent variation with direction. The interior of grooves with widths less than ~ 100 m are bowl shaped and show well developed symmetry. Wider grooves show irregular slopes and frequently have a stepped appearance that is similar to down-faulted blocks within tensional graben.

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